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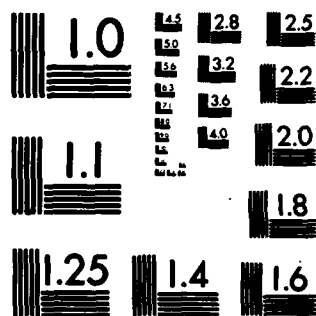
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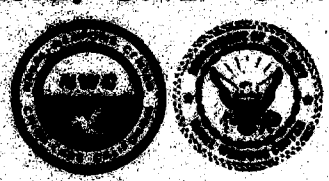
# An Investigation of Safety Hazards and Reliability Problems in Aerial Refueling Stores

by  
Leo D. Budd  
Fuze and Sensors Department

AUGUST 1980

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## FOREWORD

This is the final report on the results of an investigation of safety and reliability problems in aerial refueling stores. The work reported was conducted between March and July 1980 by the Systems Survivability Branch, Naval Weapons Center under AIRTASK A512-512C/000-4/0512-000-071, Work Unit Assignment A530313D-01.

Conclusions and recommendations regarding reliability and safety in aerial refueling stores are presented.

This report has been reviewed for technical accuracy by K. W. Bailey.

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(U) *An Investigation of Safety Hazards and Reliability Problems in Aerial Refueling Stores*, by Leo D. Budd. China Lake, Calif., Naval Weapons Center, August 1980. 71 pp. (NWC TP 6218, publication UNCLASSIFIED.)

(U) An investigation was conducted to identify sources of safety hazards and reliability problems in model D-704 aerial refueling stores. A failure modes and effects analysis was performed on the D-704. Mishap data, safety UR (unsatisfactory report) data, and 3-M (maintenance and material management) data were analyzed to identify historical problems.

(U) Comparisons of model 31-300 failure statistics to model D-704 failure statistics is included.

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## INTRODUCTION

The Douglas Aircraft Co. model D-704 aerial refueling store (Buddy Store) is an aerodynamic pod carried on an aircraft external stores rack. It is a self-contained fueling store designed to convert a combat aircraft into a fueling tanker capable of transferring fuel to a receiver aircraft while in flight. The store is 202.5 inches long, weighs about 700 pounds, has a maximum diameter of 30 inches, and can be mounted on either 20- or 30-inch hooks. It has an internal fuel capacity of 300 gallons and is capable of pumping this fuel (and any fuel that can be transferred into the store) to a receiver aircraft. Transfer of fuel from the store to the receiver aircraft is done at the rate of approximately 200 gallons per minute with a delivery pressure of from 35 to 55 psi.

A similar store, the Sargent-Fletcher Co. model 31-300, is also discussed in portions of the text.

As a result of degraded readiness of aerial refueling stores and three fires in D-704 stores in 1978 and 1979, NAVAIR tasked the Naval Weapons Center to perform a failure modes and effects analysis (FMEA), to research the probable causes of fires, and to investigate reliability problems of these stores.

## PROGRAM TASKS

### FAILURE MODES AND EFFECTS ANALYSIS

The completed D-704 Aerial Refueling Store FMEA is included as Appendix A. Although the FMEA delineates failures that are theoretically possible, it does not establish any probability of occurrence for any given failure mode. The rate at which failures occur must be established from unsatisfactory reports (URs), mishap reports, and maintenance and material management (3-M) data. However, by applying some judgment, it is possible to extrapolate which failures are relevant to the problems experienced in recent Fleet operations. For example, the FMEA reveals that all failure modes that affect the electrical, hydraulic, or mechanical timing of the hose reel are probable causes of hose breakage. Included as possible failure sources are such components as the reel-in snubbing valve, hose tension regulator, level wind assembly, solenoid valves, microswitches, and relays. Also, any component that causes loss of electrical power or loss of hydraulic fluid will disable the store and may cause hose breakage.

By extrapolation, it appears that the failure modes most likely to produce fire in the tailcone section are guillotine breakage during hose jettison and electrical short circuits. These two failure modes create a powerful source of ignition capable of initiating fires and explosions. The guillotine



may explode or it may vent hot gases that can ignite spilled hydraulic fluid or jet fuel. An electrical short of either 115 vac or 28 vdc can ignite spilled flammable fluids or arc to a fluid line and puncture it.

The FMEA does not specifically list ignition of flammable fluids as a failure mode. Rather, all electrical wires and all components that exhibit a short-circuit failure mode are considered as a source of ignition.

## FAILURE DATA ANALYSIS

### Mishap Data and Safety UR Data

Mishap data, dating back to 1969, on refueling stores was obtained from the Naval Safety Center (NAVSAFECEN) for use in evaluating which failure modes have historically been safety problems. Safety UR data was also obtained for this purpose. Appendix B summarizes the failures relevant to safety. The most catastrophic failure that occurred more than once was fire. Appendix C gives additional information on the six D-704 fires. Similarities among the five fires in the A-7 aircraft community suggest that the guillotine initiated all of these fires during hose jettison. One of these fires is known to have been initiated by the guillotine when the hose jettison switch was operated by the pilot of an A-7 aircraft. The one remaining fire occurred in a D-704 carried on an A-6E aircraft. The A-6E crew was having fuel transfer problems with this store, and two F-14 aircraft being refueled received intermittent fuel flow from the store. An explosion occurred and fire persisted in the tailcone section. It is possible that the A-6E crew activated the hose jettison switch while attempting to cycle the "to store" switch to get fuel into the store. It is also possible that the malfunctioning store electrical system fired the guillotine. In either case, the explosion of a defective guillotine could account for the explosion and fire. It is therefore possible that guillotine activation initiated all six D-704 fires. The data shows no fires in 31-300 stores, which use a different guillotine and cartridge (Mk II Mod 1) than the D-704 guillotine and cartridge (Mk I Mod 3).

In Appendix B, the failure mode "Guillotine failure" refers to incidents where the guillotine failed to function because of a defect in the guillotine or associated wiring. The failure mode "Inadvertent hose jettison" refers to guillotine firings initiated by human error, and the failure mode "Uncommanded hose jettison" refers to guillotine firings occurring from unknown causes with the hose jettison switch in the off position.

The failure mode "Structural failure" is expanded for additional information as Appendix D. Considering the age of this equipment, it is probable that the number of structural failures exceeds what is shown in this data. Since the fatigue life of these stores is unknown and the usage rate is variable and not well documented, no one can accurately predict the time when the stores will become structurally unserviceable.

The failure mode "Wiring harness" in Appendix B totals 37 failures, of which 34 occurred between 1970 and 1977 on A-7 aircraft. These failures are attributed to the fact that the original adapter harnesses were too short for use on the A-7 aircraft and consequently were often overstressed during installation.

The failure mode "Hose defect" refers to refueling hose failures. It does not include the large number of incidents in which the squadron cited a defective hose and further investigation revealed that the hose reel was improperly timed and did not snub upon hose extension. The hoses do not

seem to be failing at a high rate, except when failure is induced by improper timing, snubbing loss from hydraulic leakage, or misrigging of the hose on the drum.

Many of the columns in Appendix B overlap, in that one incident may have encompassed failures that are tabulated in several columns (i.e., a hydraulic leak may have caused snubbing malfunction, retract malfunction, or response malfunction.) Appendix E lists the total number of refueling store mishaps by type of aircraft. No attempt was made to correlate these mishap rates with the total flight hours with refueling stores installed, since records are not readily available.

### 3-M Data Review

Specially prepared 3-M reports on refueling stores were obtained from the Naval Maintenance Support Office, Mechanicsburg, Pa. The data covered all D-704 and 31-300 work unit codes (WUCs) for the period between January 1978 and December 1979. Appendix F contains a summary of some of the more meaningful failed parts data. The paucity of items reported through 3-M results in difficulty in analyzing failures due to lack of sufficient data.

Appendix G is removed components data; here again, the small amount of information available precludes any meaningful analysis.

### DISASSEMBLY AND INSPECTION OF ONE D-704

An operational refueling store was assigned to this project for disassembly and inspection. D-704 Ser. No. 435 (Part No. 5547000-527) was used to verify that configuration of a typical store is consistent with the configuration identified in the appropriate publications. Inspection of this unit was conducted to determine the physical condition of a typical store.

The logbook for Ser. No. 435 indicated that the store had accumulated 13.5 total flight hours, including 1.5 operational hours, since overhaul at the Naval Air Rework Facility (NARF), Alameda, Calif. Visual examination of the exterior revealed no defects or damage. It was found that the scarfed drain tube for the dump valve outlet was not installed. Lack of the drain tube could result in fuel being reingested into the tailcone section during fuel dumping, a condition that could lead to an explosion if the guillotine was subsequently fired.

Interior examination revealed several adverse conditions. Corrosion was found inside the guillotine cylinder that normally houses the cartridge. Other components and the structure were found to be essentially free from significant corrosion. Lack of noticeable corrosion is attributed to the desert environment in which the store had operated since overhaul.

The refueling hose (Figure 1) appeared to be nearly new, and yet it had several chafed spots in the outer cover. Chafing was traced to the level wind assembly and the level wind drive chain. Further investigation revealed that the hose reel was improperly timed, resulting in the hose riding askew on the drum and producing the chafing. The timing problem also let the drum overtravel in the extend direction: overtravel might damage the hose or cause the drum to strike the guillotine breech cap electrical connector (Figure 2). There were dents in the drum "hat" section, indicating previous contact with the guillotine electrical connector. It was possible to rotate the electrical connector to a position in which the hose would rub it (Figure 3). There is no positive means of locking the connector in a given orientation to prevent this rubbing. A few leaves of the drogue had bent tips, although the drogue appeared serviceable. One wire was broken at the soldered connection



FIGURE 1. Evidence of Refueling Hose Chafing on Level Wind Drive Chain.

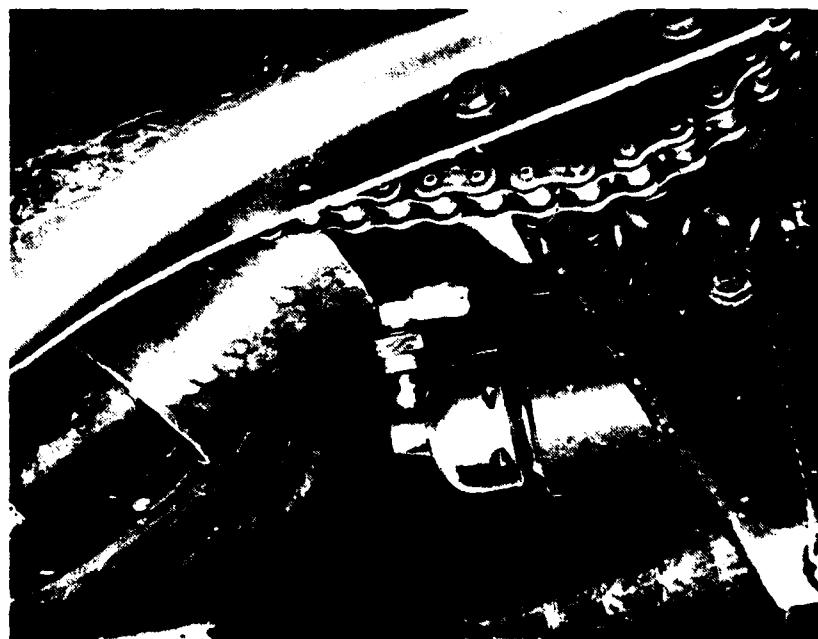


FIGURE 2. Hose Reel (Drum) Striking Guillotine Breech Cap Electrical Connector.

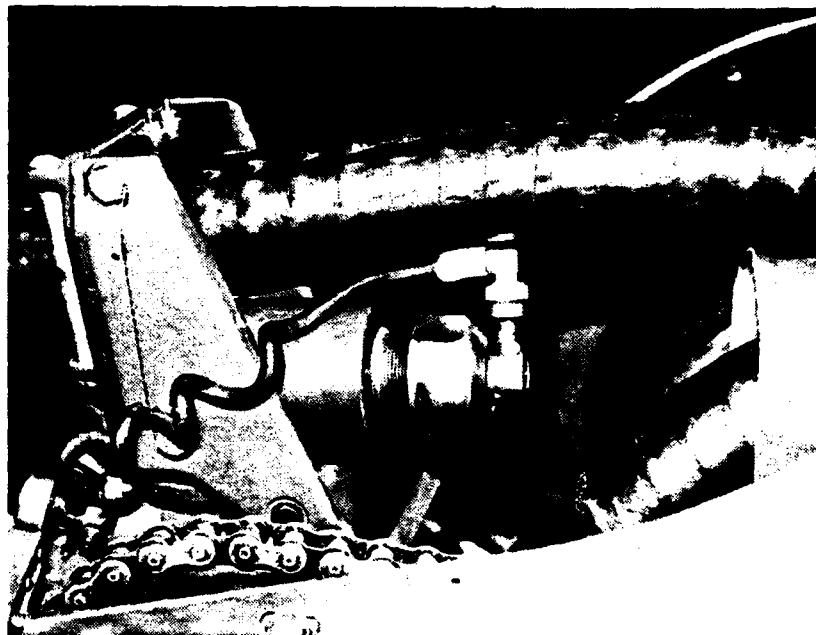


FIGURE 3. Hose Rubbing on Guillotine Breech Cap Electrical Connector.

to a dimming resistor for the tailcone indicator lights (Figure 4). Most wiring was intact, and insulation on the wires was sound. The large number of spliced wires indicated several past problems.

In the center section, the part access cover retaining chain was broken.

As shown in Figure 5, hydraulic fluid was leaking from one fitting at the hydraulic pump in the nose section. Several screws (bolts) used to attach the nose section access panel were of incorrect grip length.

External examination of the cockpit control console revealed an unauthorized modification of the hose jettison switch guard. Safety wire had been installed to hold the switch cover in place between the sides of the guard (Figure 6). Normally, the cover rests on sides of the guard and is held only by spring tension. The wire could not be broken by finger pressure on the cover since the wire was not light-gauge shear wire. The jettison switch could not be operated without first prying this wire off.

Internally, the console appeared sound, and a complete circuit continuity check revealed that all circuits conformed to the latest wiring diagram. Figure 7 is an internal view of the control console.

Two items that surfaced in the FMEA as possible design faults in the D-704 were checked by further observation of the store. The first was an ambient pressure vent for the fuel pressure regulator valve that appeared, in a schematic diagram, to be a possible path for fuel leakage into the tailcone section. As indicated in Figure 8, a trace of this vent port located its exit directly above the fuel pump hydraulic motor. The second item was a possible short circuit to the guillotine cartridge in a wire downstream of the hydraulic pressure switch (see Figure 9). It was determined that the guillotine wire could short to a 28-volt wire in that location or that the guillotine wire could become grounded.

Comparing the condition of Ser. No. 435 to the condition of other stores reported by the Naval Aviation Engineering Service Unit (NAESU), Oak Harbor, Wash.; Fleet units; NARF Alameda;

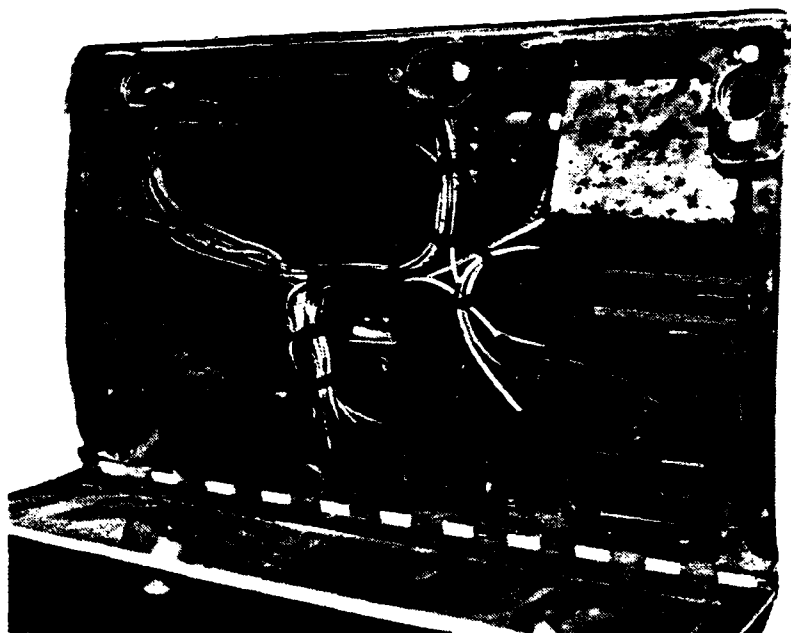


FIGURE 4. Transformer-Rectifier Assembly; Broken Wire at Dimming Resistor.

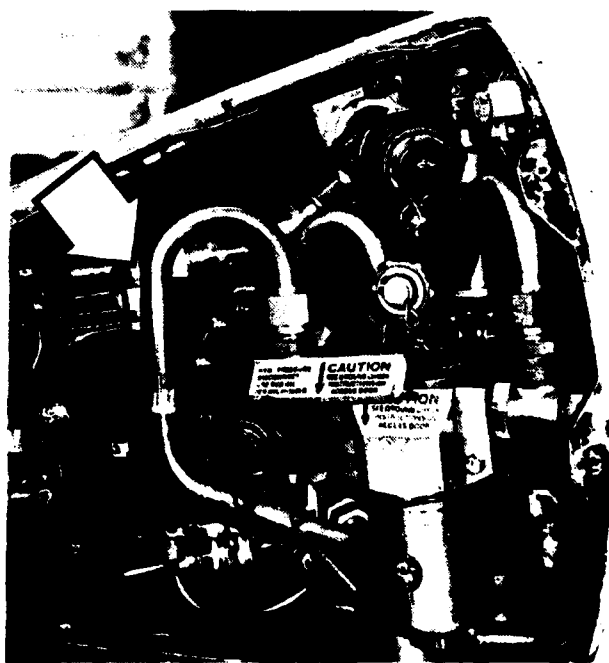


FIGURE 5. Nose Section of D-704. Arrow indicates location of hydraulic fitting leak in Ser. No. 435.

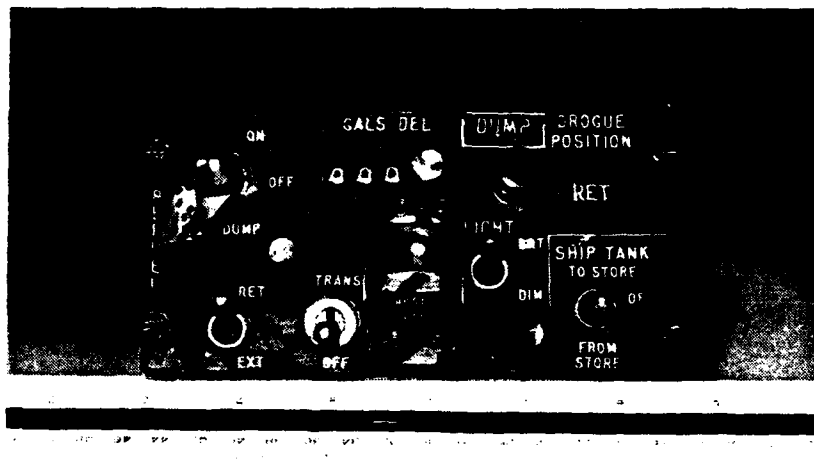


FIGURE 6. D-704 Control Console Showing Safety Wire Installed on Guillotine Switch.

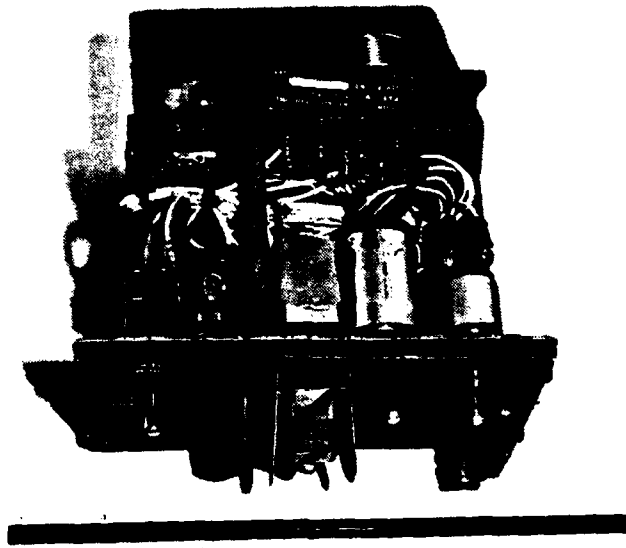


FIGURE 7. Refueling Store Control Console.  
(Viewed from bottom.)



FIGURE 8. Fuel Pressure Regulator Vent Tube Terminating Near Fuel Pump Hydraulic Drive Motor.

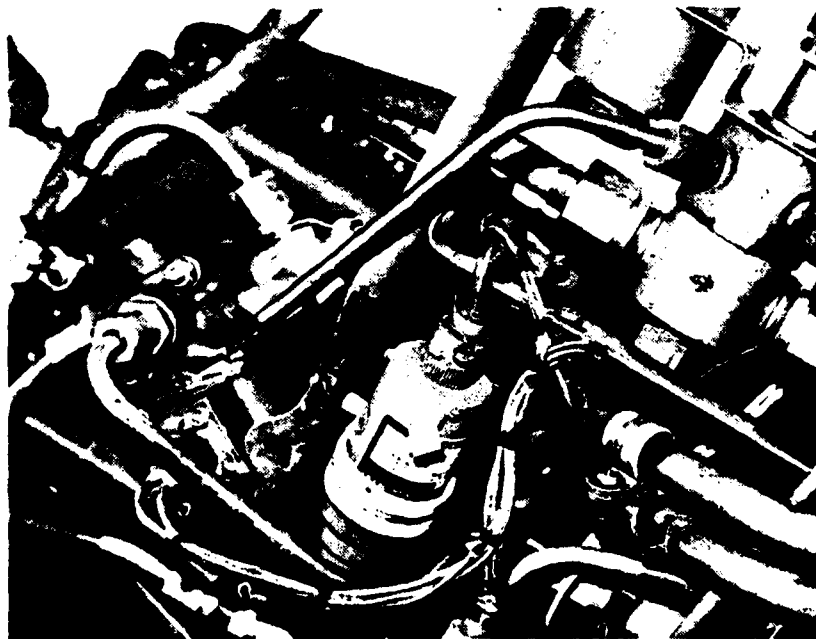


FIGURE 9. View Looking up at Hydraulic Pressure Switch.

and the Aircraft Intermediate Maintenance Department, Naval Air Station (AIMD, NAS), Lemoore, Calif., it appears that this store was in better repair than the average. Upon release from this project, Ser. No. 435 was shipped to AIMD, NAS Lemoore, where it was brought to a ready-for-issue (RFI) condition in a reported elapsed time of 3 hours.

## **REVIEWS AND INVESTIGATIONS**

### **Review of Changes, Bulletins, LESs**

Accessory changes, bulletins, and NARF local engineering specifications (LESs) were reviewed to check for reliability problems that might have been introduced by past modifications. A hydraulic reducer, MS21916D10-8, installed by accessory change AYC 33 was identified as a source of numerous hydraulic leaks.

### **Comparison of Fleet and NARF Maintenance Experiences**

Discussions with engineering and maintenance personnel at NARF Alameda produced several comments on current trends. The overhaul concept applied to refueling stores involves receiving inspection, removal of certain major components for refurbishment, corrosion control, reassembly, and operational checkout on a test stand. Many components are never removed from the store for refurbishment except when found to be faulty. This results in stores leaving overhaul with components that may not be good for one flight before failure.

The fuel pump was cited as a continuing source of leaks into the tailcone section. Improper installation of the fuel pump and the mating fuel pump drive motor can misalign the seal between the center and tailcone sections. This misalignment also prestresses the fuel pump shaft, contributing to the problem of a continuing need for overhaul of fuel pumps.

Corrosion of the rectifier, failed dump valves, and leaking hydraulic restrictors were identified as frequent occurrences. Broken hinges and shafts on the fuel shutoff valve (Part No. 131015) also occur regularly. NWC engineering personnel recommended that NARF Alameda design a correction for this weakness to alleviate a safety hazard associated with fuel siphoning. The effort is reportedly under way at NARF Alameda.

Many components are extremely worn from years of operation, and a large rate of wear-out failures is contributing to the current lack of sufficient spare parts. Cannibalization of parts, such as the hose tension regulator, is a common practice by squadrons sending stores to overhaul. A majority of stores arrive without hoses and drogue coupling assemblies, either because of a fired guillotine or because of cannibalization.

Guillotines and hydraulic drive motors were reported to be low-failure-rate items.

Forty Sargent-Fletcher Co. model 31-300 refueling stores were being held RFI at NARF Alameda since Fleet units would not accept these stores. The often-cited reason for refusal of a 31-300 is a lack of maintenance training on timing of the reel. Mechanical and hydraulic differences in the hardware require specific knowledge of 31-300 systems in order to perform maintenance.

Pilots and maintenance personnel at NAS Lemoore were asked about recent experience with refueling stores. Inadequate publications, inadequate training, and lack of sufficient quantities of spare



parts were often mentioned as problems. Frequent hardware failures included microswitches, T-5 (drogue stowed) switch actuating arms, fuel quantity probes, and night lighting generators. Improper adjustment of the hose reel timing and unintentional actuation of the guillotine were mentioned as significant maintenance errors that occur too frequently. AIMD Lemoore is preparing a rapid action minor engineering change (RAMEC) to provide a more positive indication of hose jettison switch position. AIMD Lemoore has also submitted a deficiency report on the most recent maintenance instruction manual, noting that the timing procedure gives erroneous settings.

### Guillotine Cartridge History

Informal discussions with engineering personnel at the Naval Ordnance Station (NOS), Indian Head, Md., indicated that the Mk I Mod 3 cartridge in the D-704 guillotine is outmoded and is the only cartridge of this type still in use. Recent history on the Mk I Mod 3 does not indicate any problems in reliability (i.e., the cartridge fires when triggered).

The hazards of electromagnetic radiation to ordnance (HERO) suppression device in the guillotine electrical wire is also an outmoded design and may be inadequate for the environment on a modern aircraft carrier deck.

### Discussions with Sargent-Fletcher Co.

At the request of NAVAIR, NWC personnel visited the Sargent-Fletcher Co., El Monte, Calif., to assess the model 28-300 (Pan Avia) refueling store as compared to the model 31-300. The basic operating principles are the same, although certain older design parts such as hydraulic fittings have been replaced by newer hardware in the 28-300. Hydraulic line sizes in the nose section were increased for the 28-300 to reduce friction losses and improve the available power at the tailcone section. All 28-300 electrical circuits operate on aircraft 28-vdc power, and therefore the 115-vac transformer-rectifier unit of the 31-300 is not incorporated in the 28-300. A new control console has been designed for use with the 28-300. It has red, yellow, and green indicator lights that correspond to lights of the same colors in the tailcone of the store. The 28-300 and its control console do not have a fuel dump feature because of fuel costs and environmental pollution considerations.

There are no major state-of-art improvements in the 28-300, although the elimination of the 115-volt to 28-volt power conversion equipment is an improvement in safety and reliability over the 31-300 design.

### Review of KC-10 and 28-300 Data

Another task that was added to the project at NAVAIR's request was a review of failure modes and reliability predictions on the latest Sargent-Fletcher hose reels for comparison with D-704 data. Courtesy copies of the following documents were obtained from the Sargent-Fletcher Co.:

1. S-F Report No. 43.646, Maintainability Brochure and Operator's Handbook-Tornado Buddy/Buddy Refueling Pod
2. S-F Report No. 43.641, Reliability Analysis Report-Tornado Buddy/Buddy Pod

3. S-F Report No. 43.650, Reliability Estimate—Model FR600D Hose Reel Installation—KC-10A Aircraft

4. S-F Report No. 43.651, Failure Modes & Effects Analysis—Model FR600D Hose Reel Installation—KC-10A Aircraft

The KC-10 FMEA very closely parallels the FMEA of Appendix A. Individual failure modes in the two FMEAs vary slightly because of hardware differences.

Sargent-Fletcher Co. prepared the KC-10 reliability estimate based on reliability handbook information. Although it appears that the estimate is meticulously prepared, actual failure rates of similar equipment were not available to Sargent-Fletcher for establishing estimated KC-10 refueling system reliability. The same technique was used in preparing the model 28-300 reliability analysis.

#### **D-704 NIP and Magazine Article on Safety**

The last task added to the project at NAVAIR request was to draft a magazine article relating the safety hazards of the D-704 fires,\* and to present this same information at the D-704 "Not Mission Capable" Improvement Program (NIP) meeting at NAS, Cecil Field, Fla.

Additional information obtained at the NIP meeting included the fact that AIMD at NAS Lemoore had discovered two control consoles with wiring interconnecting the fuel dump light press-to-test switch and the hose jettison switch. NAESU, Whidbey Island, Wash., reported tailcone damage from carrying 31-300 stores on the A-6 aircraft.

#### **Investigation of Failed Guillotine**

A planned investigation of the D-704 guillotine Ser. No. 270, which shattered during a preflight inspection, was not carried out. Ser. No. 270 was not shipped to NARF Alameda for investigation; and when located, it had already been repaired and was back in operation.

### **CONCLUSIONS**

The overall deficiency in reliability and safety in aerial refueling stores stems from several individual problems, and it will be necessary to address each of these separately to achieve a significant improvement in safety and reliability.

A significant safety hazard exists in the guillotine assembly. Disintegration of the cartridge cylinder (breech) or the breech cap is a single failure that can easily produce a fire or an explosion. This fact, along with the cost of lost equipment and the cost of aborted missions, makes it very important that the need for hose cutting be reduced.

\* Submitted to Naval Safety Center, Publications Department, for use in *Approach* magazine.

Unplanned firings aggravate the safety hazard associated with the guillotine. Unintentional cutting of the hose is largely due to human error. Maintenance personnel cut new hoses too frequently by not resetting the hose jettison switch to off after replacing a cut hose. Flight crews cut hoses unintentionally through errors in switch selection. Additional unplanned guillotine firings are often unexplained if the hose jettison switch was in the off position. These firings may be due to stray voltage, poor electrical system condition, improper wiring, or a HERO safety deficiency.

The shorting of the transformer-rectifier, which occurs when the inductor strikes it, is a safety hazard. This could cause overheating or sparking anywhere within the store. Fire or catastrophic electrical malfunction are possible results.

Internal breakage of the fuel shutoff valve is another safety hazard. Any severed or leaking refueling hose could siphon fuel into the tailcone section if the shutoff valve is not properly closed.

Improperly wired control consoles capable of firing the guillotine when the dump light is depressed are also a safety hazard both during maintenance checks and during flight operations.

Hydraulic leaks are a major contributor to such malfunctions as retract mode inoperative, response mode inoperative, extend snubbing mode inoperative, and fuel transfer mode inoperative. Hydraulic fittings, restrictors, and disconnects account for much of the leakage. Major components such as the pump, hydraulic motors, and solenoid valves leak less frequently.

Electrical system malfunctions occur in the transformer-rectifier, in deteriorated wiring, and in microswitches. Much of this low reliability stems from the age of the equipment and the lower inherent reliability of 1950s discrete components compared to today's solid-state circuitry. Many of these malfunctions eliminate refueling capability since there is no redundancy in the system.

Mechanical problems are chiefly associated with hose reel timing. Without proper timing, the hose reel and level wind assembly will be subject to induced failures. Failures may include damage to the reel assembly, the level wind, the refueling hose; or any tailcone section component that is struck when one of these listed components fails.

Stronger emphasis on training is needed to reduce the rate of induced failures. Specific training in maintenance of 31-300 stores should be added to the available D-704 instruction.

## RECOMMENDATIONS

Immediate attention is needed to correct the safety hazard within the D-704 guillotine assembly. A test program at NOS Indian Head is recommended. NOS Indian Head can fire the guillotine and determine if both cartridge and guillotine are performing properly. It is also recommended that NARF Alameda conduct a nondestructive test and investigation (NDTI) on several guillotines and then section them for metallurgical analysis. This is a simple approach to uncovering the source of guillotine disintegration.

A HERO analysis of the D-704 guillotine assembly should be conducted to determine the need for HERO testing. HERO suppression may be inadequate for today's carrier deck environment.

Incorporation of a new hose jettison switch to reduce unintentional hose cutting is recommended.

Removal of the 115-volt electrical system from both D-704 and 31-300 stores would eliminate transformer-rectifier shorting. This approach has the potential disadvantage of necessitating that all aircraft supply sufficient 28-vdc power for all refueling store functions. An alternative would be to

replace discrete transformer-rectifier assembly components with an equivalent solid-state circuit. Informal liaison with Sargent-Fletcher Co. engineering personnel indicates that a modular device of a suitable type is currently available. It is recommended that one of these two approaches to elimination of the existing transformer-rectifier be implemented. As a short-term alternative, improved retention of the inductor is recommended to reduce the occurrence of shorting.

Additional electrical system deficiencies in wiring and microswitches should be corrected to improve reliability. Complete re-wiring of the stores is recommended. Re-wiring should include upgraded guillotine wiring with better insulation and improved HERO suppression. Also recommended is the replacement of microswitches with a more modern, higher reliability switching device.

A bulletin to inspect for control consoles with improper wiring is needed immediately to prevent additional unintentional hose cutting.

Reinforcement of the fuel shutoff valve in the D-704 is recommended. A check of fuel pump surge characteristics is also recommended to investigate a possible source of induced failures in the fuel shutoff valve.

Hydraulic system leakage warrants an effort to improve reliability. Replacement of the pump-to-filter line with a flexible hose or other vibration-tolerant part is recommended. The hydraulic pump surge characteristics should be investigated as a possible source of excessive vibration in the hydraulic system. Another line recommended for change is the real lock tube (pressure line). Other hydraulic system changes should include replacement of older design servicing disconnects and tube end fittings with newer design hardware. Replacement of MS21916-type reducers is also recommended.

Expedited implementation of accessory AYC 666, the hydraulic restrictor, would improve reliability by reducing hydraulic solenoid valve jamming.

Major hydraulic system components do not require design changes; however, a revised overhaul procedure should be implemented to ensure that hydraulic components are reworked prior to failure as opposed to the current overhaul procedure of not reworking most hydraulic components unless they are failed. This approach has the disadvantage of increased labor and therefore increased cost; however, the current not mission capable (NMC) rate for refueling stores indicates a need for upgrading overhaul procedures.

A change is recommended to the drogue-stowed switch (T-5) actuating arm to reinforce it and reduce the tendency for distortion and jamming.

Many mechanical malfunctions are caused by improper timing of the hose reel assembly. Immediate publications updating to correct and expand timing and troubleshooting procedures is recommended. Training should also be upgraded to include specific emphasis on 31-300-peculiar maintenance and timing procedures.

In view of the criticality of reducing refueling store NMC rates, the following recommendation describes a three-phase readiness improvement program.

**Phase I. Short-Term Corrective Actions.** This phase should include immediate implementation of all organizational-level maintenance actions that are readily available, including

1. Inspection bulletin on control console wiring defects.
2. Hose jettison switch RAMEC
3. Inductor retention RAMEC
4. AYC 666 hydraulic restrictor installation

**Phase II. Changes and Aeronautical Equipment Reliability and Maintainability Improvement Program (AERMIP).** Individual changes could be pursued to address several of the previous recommendations. Separate actions may be desirable for safety hazards such as the guillotine and the

transformer-rectifier deficiencies. However, for the remaining changes it is recommended that an AERMIP proposal be prepared. In the proposal, a variety of important reliability improvements could be prototyped and documented. The AERMIP prototype configuration would then serve as a basis for a single omnibus reliability improvement engineering change proposal. Suggested changes for AERMIP prototyping are

1. Pump-to-filter and reel lock tubing change.
2. Replacement of critical fittings and servicing disconnects where feasible.
3. Guillotine assembly change to correct disintegration tendency.
4. Replacement or removal of 115-volt electrical components.
5. All new wiring and new switching devices
6. Reinforced fuel shutoff valves.
7. Reinforced T-5 switch actuating arm and "solid shroud" to replace the drogue shoes and reduce T-5 switch arm damage occurrences. Shroud would be similar to KA-6D hardware
8. Replacement of MS21916-type hydraulic reducers.
9. Improved HERO suppression for guillotine cartridge.

**Phase III. Service Life Extension Program (SLEP).** In order to continue to operate existing refueling stores beyond the immediate near future, it is recommended that a SLEP be instituted. This program could extend beyond the AERMIP configuration to include

1. A totally new electrical system based on high-reliability solid-state circuitry. (This would complete the improvement begun under AERMIP.)
2. Replacement of all older design hydraulic disconnects and tube end fittings. (Another extension of AERMIP configuration.)
3. New guillotine and cartridge with optimized HERO suppression.
4. Structural rework to extend fatigue life and reinforce past repairs.
5. New design components to replace logistically unsupportable out-of-production components.
6. Compatibility changes to facilitate use on new aircraft designs.

The three-phase program outlined above encompasses a quick-turnaround improvement in the NMC trend followed by actions to achieve acceptable readiness for a limited period. To meet future needs and to replace attrition losses, it will become necessary to procure new aerial refuel stores. It is recommended that a development program be initiated as soon as possible to permit new design hardware to be introduced into the inventory in a manner that is cost effective (i.e., new hardware should have a life cycle cost low enough to make procurement of new stores less costly than maintaining existing hardware in suitable condition for the future needs of the operating forces). The following are desirable features that should be sought in a newly developed design:

1. Safety improvements such as modern HERO protection.
2. Reliability improvements such as solid-state circuitry and other components with higher inherent reliability.
3. Redundancy of function within systems, where feasible, to reduce aborted missions.
4. Operational modes for degraded conditions, possibly including a back-up system for one-time retraction of the refueling hose in the event of failure of the primary system.
5. Reliability-enhancing features such as reduced parts count and improved hydraulic system (or elimination of the hydraulics).
6. Size and weight improvements such as could be achieved by using solid-state circuitry and a high-pressure hydraulic system.
7. Maintainability improvements such as modular electrical system replacement assemblies and built-in test equipment (BITE).

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Appendix A

FAILURE MODES AND EFFECTS ANALYSIS

Component name	Function	Failure mode	Effects	Remarks
ON/OFF/DUMP Switch	Supply electrical power to transformer-rectifier or fuel dump valve.	Short to ON	Transformer-rectifier energized and ram air turbine unfeather solenoid energized. Reel lock opens at 1700 psi hydraulic pressure.	Deenergized retract solenoid valve holds drogue in stowed position unless extend/retract switch is placed in extend. Refueling is available.
		Short to DUMP	Fuel dump valve energized.	Fuel dumping occurs until terminated by low level float switch. Refueling is not available.
		Open to ON:		
		Upstream of switch or downstream of power interlock node	Transformer-rectifier cannot be energized or ceases to be energized.	Reel latches regardless of drogue position. Refueling is not available.
		Between switch and power interlock	Failure prior to drogue ejection prevents transformer-rectifier from being energized.	Refueling is not available.
			Failure after drogue ejection does not interrupt refueling. Drogue stowed switch maintains power to transformer-rectifier via power interlock until drogue is stowed.	Refueling is available until after drogue is stowed. Then refueling is no longer available.
		Open to DUMP	Fuel dump valve cannot be energized and/or wing tank solenoid cannot be energized.	Fuel dumping is not available and/or fuel cannot be transferred to D-704.

Component name	Function	Failure mode	Effects	Remarks
EXT/RET Switch	Energize retract solenoid valve	Short to extend	Retract solenoid energized whenever power is on.	Drogue is extended whenever power is on. Retraction of drogue is inhibited. Normal refueling is available.
		Open to extend/retract	Drogue cannot be deployed in air-stream (drogue retracts if deployed at time of failure).	Refueling is not available.
TRANSFER and OFF Switch		Short to TRANSFER (or jam in TRANSFER)	Fuel pump solenoid valve energized whenever drogue is in refueling range.	All engagements result in fuel transfer.
		Open to TRANSFER Open circuit to holding coil or short around coil	Fuel pump solenoid valve cannot be energized. TRANSFER switch returns to off when released.	Refueling is not available. Dry plugs for training are possible. Pilot must hold TRANSFER switch to conduct refueling.
BRT/DIM Switch	Energize dimming relay (to ready and transfer lights)	Short to DIM	Ready and transfer lights function on dim setting only.	
		Open to BRT/DIM contacts	Ready and transfer lights function on bright setting only.	



Component name	Function	Failure mode	Effects	Remarks
SHIP TANK Switch (to store/from store)	Energize/deenergize store air solenoid valve and wing tank pressure and vent valve	Short to TO STORE	Wing tank solenoid valve pressurizes wing tank (or tanker transfer pumps energized). D-704 is continuously filled with fuel whenever float and vent valve is open (i.e., fuel level is below float and therefore float has not actuated pressurization of store).	Normal refueling is available. Fuel dumping is available and will dump aircraft fuel in addition to D-704 fuel. Hose jettison is available. Transfer of D-704 fuel into tanker aircraft is not available.
		Short to FROM STORE	Store air solenoid valve deenergizes and pressurizes D-704. D-704 transfers fuel into tanker aircraft until low level float switch signals depletion of D-704 fuel.	Normal refueling is not available. Refueling is possible until D-704 is empty.
		Open to TO STORE	Wing tank solenoid valve (or transfer pumps) cannot be energized. D-704 cannot be refilled.	Some aircraft may be able to transfer fuel to the D-704 by alternate means such as transfer pump activation or fuel tank pressurization. This alternate procedure will possibly transfer fuel to all external fuel tanks including the D-704.
		Open to FROM STORE	Store air solenoid deenergizes. Store pressurizes and transfers fuel to tanker aircraft. Store remains pressurized after fuel depletion.	
HOSE JETTISON Switch	Deenergize transformer-rectifier and energize hose cutter	Short to HOSE JETT (both poles of switch)	Refueling hose is cut.	Refueling is not available. D-704 can be used as a 300-gal external fuel tank. Fuel dumping is available.

Component name	Function	Failure mode	Effects	Remarks
HOSE JETTISON Switch (cont.)		Short to HOSE JETT (hose jettison pole of switch only)	Refueling hose is cut any time hydraulic pressure drops below 350 $\pm$ 50 psi.	Hose reel will be latched prior to hose jettison. Refueling is not available.
		Open to HOSE JETT (hose jettison pole of switch only)	Hose jettison function is disabled.	Refueling is available.
		Open to HOSE JETT (power pole of switch only)	Electrical power to the ON/OFF/DUMP switch is disabled.	Refueling is not available.
		Open to HOSE JETT (both poles of switch)	Hose jettison is disabled and electrical power to ON/OFF/DUMP switch is disabled.	Refueling is not available and jettison is not available. If hose was extended at time of failure, pilot must jettison D-704 or land with hose trailing from D-704.
DROGUE POSITION INDICATOR	Indicate (to tanker aircraft pilot) the position of the drogue	Short between EXT and power wire, short between TRA and power wire, open to EXT, open to TRA	Indicator will not read correctly for various drogue positions.	Refueling is available.
DUMP LIGHT	Indicate power is being applied to fuel dump valve and fuel level is above "low"	Short on or short to ground	Erroneous indication of fuel dumping.	Pilot can monitor fuel quantity in D-704 and identify this failure. Refueling is available.

Component name	Function	Failure mode	Effects	Remarks
DUMP LIGHT (contd.)		Open circuit	Lack of dump indication.	Pilot can monitor fuel quantity and identify this failure.
GALLS/DEL COUNTER	Indicate total gallons of fuel transferred during refueling	Short to power wire	Counter runs rampant or burns out.	Refueling is available.
		Open to counter or open to ground or mechanical jam	Counter does not function.	Refueling is available.
PANEL LIGHTS or DROGUE POSITION INDICATOR LIGHTS	Provide illumination of control panel	Inoperative	Control panel illumination (at night) is reduced or eliminated.	Refueling is available.
TRANSFORMER-RECTIFIER	Convert aircraft a.c. power to d.c. power (when applicable to the particular aircraft carrying the store)	Short circuit	Overheating and/or high voltage sparking from transformer-rectifier or any electrical component in the D-704.	Refueling is not available. Heat and/or sparks may ignite any combustibles present.
		Open circuit:		
		Partial	Abnormal voltage or amperage in D-704 electrical system.	Refueling is available until abnormal power degrades to unacceptable level.
RAM AIR TURBINE SOLENOID	Feather ram air turbine	Complete	Loss of electrical power.	Refueling is not available.
		Short or open circuit	Ram air turbine feathers or remains feathered.	Refueling is not available.

Component name	Function	Failure mode	Effects	Remarks
RAM AIR TURBINE	Provide mechanical power to the hydraulic pump	Jam in feathered position or bind or break driveshaft	Hydraulic pump is unpowered.	Refueling is not available.
		Jam in unfeathered position	Hydraulic pump operates at all times.	Refueling is available. Hose cannot be jettisoned.
		Governor breakage	Ram air turbine overspeeds to failure.	Refueling is not available.
		Jam partially feathered or governor jam at intermediate position	Mechanical power to hydraulic pump is less than normal.	Refueling is available only if hydraulic pump is receiving adequate mechanical power.
			Priority valve will divert hydraulic power to hose reel drive motor and deprive the fuel pump drive motor.	Hose reel will operate; however, fuel transfer will be slow or completely eliminated. Snubbing on extension or retraction may be inadequate.
			Hydraulic power is insufficient to properly operate the reel drive motor.	Refueling is not available. Hose whip will result from attempts to engage the drogue since response is inadequate. Snubbing will be degraded or eliminated, which can cause loss of the hose upon extension.

Component name	Function	Failure mode	Effects	Remarks
HYDRAULIC PUMP	Provide hydraulic power to D-704 self-contained hydraulic system	Leak to case drain or leak to D-704 nose section	Reduces quantity of fluid in the hydraulic system. When reservoir is nearly depleted, D-704 performance will begin to degrade.	Fuel transfer capability will be reduced or eliminated. Snubbing will be reduced or eliminated. Hose reel response will be reduced or eliminated. Retraction and extension will be eliminated when flow and pressure deteriorate. Leaks, other than to case drain, will deposit flammable fluid in the nose section. High-pressure leaks may damage other components including wiring.
		Jam or break rotating parts	Hydraulic power is not available.	Refueling is not available.
		Overheat, or obstructed port to heat exchanger	Severe overheat creates a source of hot surface ignition. Severe prolonged overheat will break the pump.	Potential ignition of any spilled flammable fluid in the nose section. Refueling is not available if pump breaks.
		Rupture	Hydraulic power is not available.	Refueling is not available. Flammable fluid is spilled into nose section.
		Obstructed suction port or pressure port	Hydraulic power is not available. Overheating or pump rupture can result from continued pump rotation.	Refueling is not available. Flammable fluid may be spilled and a hot surface ignition may occur.
RELIEF VALVE (from hydraulic pump)	Relieve pump case overpressurization	Obstructed or jam	Overpressurization of the hydraulic pump cannot be relieved. Pump rupture may result.	

Component name	Function	Failure mode	Effects	Remarks
RELIEF VALVE: (from hydraulic pump) (contd.)		Fails open	Hydraulic fluid drains overboard and hydraulic power degrades until completely eliminated. Pump runs dry and overheats.	Refueling is not available. Refer to HYDRAULIC PUMP failure modes.
HEAT EXCHANGER	Cool hydraulic fluid	Obstructed	Hydraulic fluid temperature exceeds limits.	Refer to HYDRAULIC PUMP failure modes.
		Leak	Hydraulic fluid spills internally and/or externally to the nose section.	Refer to HYDRAULIC PUMP failure modes.
HYDRAULIC DISCONNECT (three each, one with check valve)		Leak	Hydraulic fluid spills in nose section.	Refer to HYDRAULIC PUMP failure modes.
HYDRAULIC RESERVOIR	Store hydraulic fluid	Plugged inlet port or outlet port	Hydraulic pump does not receive fluid through the suction line.	Refer to HYDRAULIC PUMP failure modes.
		Air bleed valve fails open or other leak	Hydraulic fluid spills into nose section and pump output degrades.	Refer to HYDRAULIC PUMP failure modes.
		Jam, break internally, or plugged filter inlet	Reservoir does not maintain proper pressure on stored fluid. Reservoir may overpressurize or hydraulic pump may receive inadequate fluid flow.	Refer to HYDRAULIC PUMP failure modes.

Component name	Function	Failure mode	Effects	Remarks
RELIEF VALVE (between filter and reservoir)	Relieve overpressurization of hydraulic system	Obstructed, jam	Overpressurization of hydraulic system and leakage may occur at locations throughout the D-704.	Refer to HYDRAULIC PUMP failure modes. Spilled flammable fluid may be present near potential ignition sources in the nose section or tail section.
		Fail open	Hydraulic system flow and pressure will degrade.	Refer to HYDRAULIC PUMP failure modes.
HYDRAULIC FILTER	Remove solid contaminants from hydraulic fluid	Leak	Flammable fluid spills into nose section.	Refer to HYDRAULIC PUMP failure modes.
		Obstructed	Hydraulic power is not available.	Refer to HYDRAULIC PUMP failure modes.
PRESSURE FUELING RECEPTACLE	Inlet connect for pressure refueling on the ground	Leak	Fuel is lost overboard and the store and para-drogue may become wetted with fuel.	Significant leakage will render it unsafe to continue refueling. The spilled fuel could be ignited by the tanker aircraft exhaust (centerline store installation) or ingested by the receiver aircraft. The fuel quantity system will register the loss of fuel (when not refueling); however, there is no corrective action possible in flight.

Component name	Function	Failure mode	Effects	Remarks
PRESSURE FUELING RECEPTACLE (cont'd.)		Jam, break, or obstructed	Ground pressure refueling cannot be accomplished.	Refueling is available.
FLOAT AND VENT VALVE	Close fuel inlet when fuel level reaches full during ground pressure refueling (direct refueling of D-704)	Fuel inlet obstructed or jammed closed	Ground pressure refueling is not available.	Refueling is available.
		Fuel inlet jammed open or float broken	Inlet will not be closed when fuel level reaches full. Fuel will vent through relief valve of float and vent valve.	No effect on airborne operations unless D-704 was damaged by overpressurization.
	Vent excess pressure or fuel	Primary air vent obstructed or jammed closed	Pressure refueling (ground or flight) and inflight transfer to store will be slow due to lack of venting. D-704 may be overpressurized.	No effect on airborne operations unless D-704 was damaged by overpressurization.
	Close primary air vent when fuel level reaches full			
	Close primary air vent and open pressure inlet when bleed air is supplied to D-704.	Primary air vent jammed open or float broken	Fuel will spill from D-704 if a full store is jarred or tilted nose down.	
		Secondary air vent obstructed	D-704 will vent fuel rather than air when thermal expansion of the fuel occurs.	



Component name	Function	Failure mode	Effects	Remarks
FLOAT AND VENT VALVE (contd.)		Relief poppet jammed closed	Excess pressure cannot be relieved rapidly whenever float valve has closed primary vent. Overpressurization may occur during transfer from full store or transfer to store.	
		Relief poppet broken or jammed open	D-704 cannot be properly pressurized for transfer of fuel from the store. Fuel may spill from D-704 if jarred or tilted nose down.	Refueling is available.
		Bleed air poppet valve jammed open or broken	Bleed air enters store whenever bleed air is supplied. (This not a problem.) Fuel can enter the bleed air line when the line is depressurized.	Fuel and fuel vapor contaminating the bleed air system is a fire hazard.
		Bleed air poppet valve jammed closed	D-704 cannot be pressurized for transfer of fuel from the store.	Refueling is available.
		Vent-closing poppet valve jammed closed	Primary and secondary vents are obstructed. Pressure fueling (ground or air) and transfer of fuel to the store will be slow due to lack of venting. Venting will occur only through the relief poppet valve. Overpressurization of the D-704 may occur.	

Component name	Function	Failure mode	Effects	Remarks
FLOAT AND VENT VALVE (contd.)		Vent-closing poppet valve jammed open or broken	D-704 cannot be pressurized for transfer of fuel from the store. Partially open valve might allow transfer of fuel from full D-704 until float valve opens primary vent. This would not be a significant quantity of fuel transferred.	Refueling is available.
GRAVITY FUEL FILLER CAP	Close gravity filler opening	Leak, detach from D-704	Fuel may spill from D-704 when jarred or tilted nose down, or when thermal expansion of fuel occurs. Fuel may be drawn from the D-704 by suction while in flight. D-704 cannot be pressurized if leakage is significant.	Refueling is available.
		Jam closed	Gravity filling of D-704 is not available.	Refueling is available.
HIGH LEVEL FLOAT Switch	Deenergize aircraft external fuel tank pilot valve when D-704 is full during pressure fueling from the tanker aircraft	Short circuit	Aircraft pilot valve remains energized and the D-704 vents fuel when full during pressure fueling.	Refueling is available.
		Open Circuit	Aircraft pilot valve remains de-energized and fuel does not enter the D-704 during pressure refueling.	Refueling is available.

Component name	Function	Failure mode	Effects	Remarks
FUEL QUANTITY PROBE AND CONNECTOR	Provide fuel quantity signal to pilot	Open circuit	No fuel quantity indication is provided to the pilot.	Refueling is available.
		Shorted or broken	Erroneous fuel quantity indication. Electrical sparks or heated conductors present ignition hazard inside D-704 center section.	Refueling is available.
FUEL INLET/ OUTLET TUBE AND CONNECTORS	Fuel transfer between D-704 and aircraft	Broken, leak	Transfer from store will terminate or slow down when fuel level reaches the leak or break. Connector may leak externally.	Refueling is available. (Connector leakage may be a hazard during transfer to store.)
		Obstructed	Fuel transfer to or from D-704 is prevented.	
ELECTRICAL CONNECTOR	Electrical connection of D-704 and wiring harness	Short or open	May cause any of the D-704 or control panel electrical devices to become grounded or ungrounded.	Refer to failure modes of individual electrical components.
BLEED AIR CONNECTOR	Connect aircraft bleed air to D-704	Leak, obstructed	Significant leakage will prevent pressurization of the D-704 for fuel transfer from the store.	Refueling is available.

Component name	Function	Failure mode	Effects	Remarks
FORWARD FUEL BELLMOUTH AND AFT FUEL BELLMOUTH	Fuel inlet to fuel pump	Broken, obstructed	Loss of only one bellmouth will result in a small quantity of trapped fuel which cannot be pumped to the receiver aircraft. Loss of both bellmouths to obstruction prevents fuel pumping. Loss of bellmouth tubing to leakage traps all fuel lower than the leak.	
LOW LEVEL FLOAT Switch	Deenergize dump light when fuel level is low during dumping	Open circuit or jammed open Short circuit or jammed closed	Dump light will not light. Dump light will not extinguish when fuel level is low.	Pilot can confirm fuel dumping by monitoring fuel quantity. Pilot can observe low fuel level on fuel quantity gauge.
DRAIN VALVE	Drain water or residual fuel from the D-704	Jam closed Jam open or break	Water or residual fuel cannot be drained. Fuel will leak from the D-704.	
DUMP VALVE	Release fuel from D-704	Jam closed or open circuit Jam open, leak, or short to energized electrical connection	Fuel dumping is not available. Fuel will spill from D-704.	Refueling is available. Refueling is not available.
FLOW METER	Actuate the gallons delivered indicator	Jam, break, or open circuit	Gallons delivered indicator will not operate.	Refueling is available.

Component name	Function	Failure mode	Effects	Remarks
FLOW METER (contd.)		Short circuit	Erroneous input to gallons delivered indicator. Sparks or heat may occur in the D-704 center section.	Refueling is available.
		Obstructed or dislodged	Fuel transfer to receiver aircraft is prevented.	Refueling is not available.
FLOW INDICATOR	Energize the transfer light	Jam closed, obstructed, or broken at inlet or outlet	Fuel cannot be pumped to the receiver aircraft.	Refueling is not available.
		Open circuit or broken switch	Transfer light will not illuminate.	Refueling is available. Both pilots can monitor fuel quantity to verify transfer of fuel. Tanker pilot can monitor gallons delivered indicator.
		Short circuit or switch jammed closed	Transfer light illuminates whenever ON/OFF/DUMP switch is selected to ON.	Refueling is available. Actual transfer can be monitored by fuel quantity.
VENTURI	Provide reference fuel pressure to the fuel pressure regulator valve	Inlet, outlet, or throat obstructed or broken	Fuel cannot be pumped to the receiver aircraft.	Refueling is not available.

Component name	Function	Failure mode	Effects	Remarks
VENTURI (contd.)		Reference pressure outlet obstructed or broken	Fuel pump drive motor will over-speed. Fuel pressure will be unregulated. Overheating or disintegration of the drive motor may occur. Either of these is an ignition source for flammable fluids spilled in the tail section. Motor disintegration terminates fuel pumping, produces hydraulic leakage, and may damage other components including the fuel pump and the aft bulkhead.	Fuel pressure may be excessive and cause damage to the D-704 or the receiver aircraft. Motor disintegration creates a potential fire or explosion hazard.
FUEL SHUT-OFF VALVE	Shut off fuel flow whenever line pressure does not exceed tank pressure by 35 psi	Jam closed, tank reference pressure port obstructed, or break externally  Break internally or jam open	Fuel transfer to the receiver aircraft is not available.  Fuel will gravity transfer by suction when fuel pump shuts off.	Refueling is not available.  Refueling is available.
FUEL PRESSURE REGULATOR VALVE	Regulate hydraulic flow to the fuel pump drive motor	Fuel reference pressure inlet obstructed or disconnected or piston jammed	Fuel pump drive motor is not regulated. Refer to failure modes for VENTURI reference pressure outlet. Jammed piston provides one set flow rate to fuel pump drive motor.	

Component name	Function	Failure mode	Effects	Remarks
FUEL PRESSURE REGULATOR VALVE (contd.)		Return port obstructed	Regulator valve will divert all hydraulic flow to the fuel pump drive motor regardless of the fuel reference pressure. This creates an unregulated motor and also creates stress in the fuel pressure regulator valve. The motor or valve may be damaged internally or may rupture.	Refer to VENTURI failure modes.
		Inlet or outlet port obstructed or disconnected	Hydraulic flow does not reach the fuel pump drive motor.	
		Fuel vent port obstructed	Accumulated fuel in pressure regulator valve housing will inhibit proper piston travel in the valve. This will choke the flow to the fuel pump drive motor and reduce or eliminate fuel flow.	Refueling is not available.
		Fuel vent port broken or leaking	Fuel spills, in small quantities, into the tail section.	
		Return port broken or leaking or leaking return line	Fluid spills into tail section or center section. Leakage will terminate fuel transfer and lock the hose reel.	
		Piston assembly broken	Hydraulic flow is unregulated to fuel pump drive motor. Fuel and hydraulic fluid may intermix.	See VENTURI failure modes.

Component name	Function	Failure mode	Effects	Remarks
FUEL PUMP	Transfer fuel to receiver aircraft	Jammed, broken, inlet obstructed, outlet obstructed Case drain outlet obstructed	Fuel transfer to the receiver aircraft is not available. Leakage around seals cannot drain overboard.	Refueling is not available.
FUEL PUMP DRIVE MOTOR	Provide mechanical power to the fuel pump	Inlet, primary outlet, or secondary outlet obstructed; or broken or jammed motor Inlet, primary outlet, secondary outlet disconnected or leak in motor Case drain outlet obstructed Case drain tube broken	Motor does not drive the fuel pump. Loss of hydraulic fluid terminates fuel transfer and locks reel. Hydraulic fluid spills into the tail section. Leakage around seals cannot drain overboard. Small quantities of hydraulic fluid leak into the tail section.	Refueling is not available. Flammable fluid is a fire hazard.



Component name	Function	Failure mode	Effects	Remarks
FUEL PUMP SOLENOID VALVE	Provide hydraulic power to the fuel pump drive motor when the drogue is in the transfer range position	Open circuit or jammed closed or inlet or outlet obstructed Jammed open or broken internally	Solenoid valve will not supply hydraulic power to the fuel pump drive motor.	Refueling is not available.
			Solenoid valve will supply hydraulic power to the fuel pump drive motor whenever system pressure is adequate to open the hose reel priority valve. Fuel pump will operate regardless of drogue position.	Pressurization of the drogue increases the force necessary for a receiver aircraft to get engaged.
		Leak	Hydraulic fluid spills into tail section.	Flammable fluid is a fire hazard.
HOSE REEL PRIORITY VALVE	Provide hydraulic power to the fuel pump solenoid valve whenever the hose reel drive motor power requirements permit	Jammed open	Hose response may be inadequate since the fuel pump drive motor is not isolated when demands on the hydraulic system increase.	Hose whip may develop if receiver aircraft is in transfer range position.
		Jammed closed Leak	Fuel transfer is not available. Hydraulic fluid spills into tail section. Loss of hydraulic fluid terminates fuel transfer and locks reel.	Refueling is not available. Flammable fluid is a fire hazard in tail section.

Component name	Function	Failure mode	Effects	Remarks
REEL-IN SNUBBING VALVE	Adjust hydraulic power to the reel drive motor to reduce speed	Arm broken or valve jammed in unsnubbed position or broken slider	Valve spring holds slider in the unsnubbed position under all conditions. Reel will not snub upon retraction. Over-travel of the reel may cause breakage of the level wind and guillotine assembly and may crimp the hose.	Attempted extension of the drogue following an unsnubbed retraction may result in loss of hose and extensive damage inside tail section.
		Valve jammed in snubbed position or obstructed inlet or outlet at slider	Reel drive motor is snubbed under all conditions. Extension and retraction will be slow. Response will be slow and therefore inadequate.	Hose whip can develop and loss of hose or receiver aircraft probe is possible.
		Obstructed snubber restriction	Hose reel will stop rotating instead of slowing to two feet per second when the snubbing lever is actuated.	Drogue cannot be fully retracted. Refueling is available.
		Obstructed inlet or outlet	Hose reel drive motor is unpowered.	Refueling can be conducted without response. Drogue cannot be retracted.
		Disconnected inlet or outlet	Hydraulic fluid spills into tail section.	Refueling is not available. Loss of response, fuel transfer, and retraction capability will occur. Flammable fluid is a fire hazard.

Component name	Function	Failure mode	Effects	Remarks
EXTEND CUT-OUT RELAY SWITCH (T-6)	Arm circuit to engage extend cut-out relay	Broken, jammed open, or open circuit:  After activation of extend cut-out relay  Prior to activation of extend cut-out relay	No adverse effects until the drogue is retracted and re-extended.  Extend solenoid valve remains energized at all times when ON/OFF/DUMP switch is on. Hose will not snub upon reaching trail position. Response is inoperative. Fuel transfer is inoperative.  Circuit to extend cut-out relay is continuously armed. Extend cut-out relay activates whenever drogue ejection switch is closed. The extend solenoid valve will open prematurely during drogue extension. This closes the return port on the hose tension regulator and restricts further drogue extension.	D-704 operation will be normal until hose reaches trail position. Loss of hose during extension or receiver aircraft breakaway is possible. Hose whip is possible. Refueling is not available.  Drogue extension may be terminated or drag on the drogue may damage the hydraulic system and proceed to extend the drogue.
CHECK VALVE (between hydraulic system filter and hose tension regulator)	Prevent reverse direction flow	Jammed open, broken	Reverse flow will occur when the upstream pressure is reduced by positioning the ON/OFF/DUMP switch to OFF. This will bleed off pressure from the hose tension regulator and may cause the regulator to allow the drogue to eject unintentionally the next time the ON/OFF/DUMP switch is selected to ON.	

Component name	Function	Failure mode	Effects	Remarks
CHECK VALVE (contd.)		Obstructed, jammed closed	Hydraulic power will not be delivered to the hose reel drive motor.	Refueling is not available.
		Disconnected, leak	Hydraulic fluid will spill into tail section. Loss of fluid will eliminate hydraulic power to the reel drive motor and fuel pump drive motor.	Flammable fluid is a fire hazard. Refueling is not available. Refer to HYDRAULIC PUMP failure modes.
REEL LOCK	Inhibit rotation of the reel any time hydraulic pressure is low	Jam locked, obstructed	Reel will not rotate. In the case of a reel in motion when failure occurs, the lock, reel, and hose will be damaged by the sudden stop or attempted stop.	Refueling is not available. The possible breakage of fuel or hydraulic components produces a fire hazard.
		Jam unlocked, break	Hose reel rotation, during periods of disuse, will be inhibited only by residual hydraulic pressure.	The possibility of inadvertent drogue ejection is greatly increased.
		Disconnected, leak	Hydraulic fluid spills into tail section.	Flammable fluid is a fire hazard. Refer to HYDRAULIC PUMP failure modes.
HOSE REEL (including gear box)	Hold and dispense the hose as needed	Jam, break	Drogue position remains constant. If reel was in motion, damage of other tail section components may occur as may loss of hose.	Refueling is not available. Fire hazard may exist.
		Free wheel (unrestricted by drive gearing to drive motor)	Drogue will extend unsnubbed breaking hose. Fuel will spill in tail section if reel assembly contained residual fuel.	Refueling is not available. Fire hazard exists.

Component name	Function	Failure mode	Effects	Remarks
HOSE REEL DRIVE MOTOR	Provide mechanical power to the hose reel gear box	Inlet or outlet port obstructed, jammed, broken, secondary outlet obstructed, leak, disconnected	Hose reel is inoperative. If hose reel was in motion when failure occurred, many tail section components may be damaged.	Refueling is not available. Fire hazard exists.
CHAIN DRIVE	Provide mechanical power to the level wind	Chain broken, chain off sprocket	Hose will not wrap on hose reel properly and will be crushed during response or retraction. Operation with crushed hose will break hose or jam hose reel.	Refueling is not available. Fire hazard exists.
LEVEL WIND	Direct the hose into the proper position as the hose winds onto the hose reel	Jammed, broken or dislocated driveshaft or carriage	Hose will not wrap on hose reel properly and will be crushed during response or retraction. Operation with crushed hose will break hose or jam hose reel.	Refueling is not available. Fire hazard exists.
GUILLOTINE	Cut and crimp the refueling hose	Cartridge fails to fire or fails to produce sufficient force, knife jams, open circuit to cartridge Cartridge fires inadvertently, short to electrical power source	Hose is not cut and crimped. Partial cutting will result in fuel spillage in the tail section. Hose will be cut and crimped.	Pilot must land with hose still deployed or must jettison the D-704. Refueling is not available. If receiver aircraft was engaged or in pre-engagement position, the hose may inflict serious damage to that aircraft.

Component name	Function	Failure mode	Effects	Remarks
GUILLOTINE (cont.)		Cartridge gases escape from breech or breech ruptures	The explosive force of the cartridge and any debris which it propels will cause damage to tail section components. This damage will eliminate refueling capability and may result in a fire or explosion.	Fire or explosion may result in the D-704. The explosion damage could include damage to the tank-er aircraft or a receiver aircraft.
REFUELING HOSE	Supply fuel to the drogue and coupling assembly	Broken, obstructed, jammed, unravelled	Hose will not supply fuel to receiver aircraft.	Refueling is not available.
HOSE TENSION REGULATOR	Regulate hydraulic flow to the reel drive motor	Lever arm broken  Drain port obstructed  System pressure port obstructed	Regulator does not supply hydraulic power in the retract direction when the drogue reaches the trail position. This will produce high loads on the hose, the reel, the gear box, and the hydraulic motor and may result in breakage.  Inability to relieve back pressure will eventually interfere with motion of the slider. Pressure regulation will be erratic and may produce other failure modes.  Response, retraction, and hose snubbing upon reaching trail position during extension are inoperative.	Refueling is not available. Drogue will extend unsnubbed with possible loss of hose. If drogue was already extended, it will remain at trail position.

Component name	Function	Failure mode	Effects	Remarks
HOSE TENSION REGULATOR (cont.)		Outlet port to reel snubbing valve obstructed completely	Reverse flow from the reel drive motor cannot occur and therefore drogue extension is inhibited. If the drag on the drogue overcomes the restraining hydraulic system, drogue ejection, the forces generated will damage mechanical and hydraulic components of the tail section. Response and snubbing at the trail position are inoperative.	Refueling is not available.
		Outlet port to reel snubbing valve obstructed at bypass to return port or return port obstructed	Reverse flow from the reel drive motor cannot occur and therefore drogue extension is inhibited. In the case of a failure after drogue extension, the response will reel hose in properly but will not reel any hose back out.	Refueling is not available. Drogue can be retracted.
		Outlet port to reel snubbing valve obstructed without the bypass to return port being obstructed	Response and retraction are inoperative.	Refueling is not available. Drogue cannot be retracted.
		Inlet port from extend solenoid valve obstructed	Snubbing at the trail position will be engaged more abruptly than normal. This may induce damage to the reel assembly or the hose. Retraction may be adversely affected. A reduction in tanker aircraft airspeed may be required to completely retract the drogue.	

Component name	Function	Failure mode	Effects	Remarks
HOSE TENSION REGULATOR (cont.)		Inlet port from retract solenoid valve obstructed or filtered restrictor obstructed	With electrical power on in the D-704, the drogue will eject and extend. Drogue cannot be retracted.	Refueling is available. Drogue retraction may be possible if tanker aircraft airspeed is reduced. Electrical power must be turned off at precisely the moment of drogue stowage to prevent re-ejection.
		Drain port leaking or disconnected	Hydraulic fluid spills into tail section. Loss of hydraulic fluid may eventually eliminate refueling capability.	Flammable fluid is a fire hazard.
		Return port leaking or disconnected	Hydraulic fluid will spill into tail section when hose extends during extension or response. Loss of fluid eventually degrades or eliminates refueling capability.	Flammable fluid is a fire hazard. Refueling is not available. Refer to HYDRAULIC PUMP failure modes.
		Outlet port to reel snubbing valve leaking or disconnected	Hydraulic fluid will spill into tail section whenever hose reel is in motion. Loss of fluid will eliminate refueling capability.	Flammable fluid is a fire hazard. Refer to HYDRAULIC PUMP failure modes. Refueling is not available.
		System pressure port disconnected or leaking	Retraction is not possible. Hose reel response is inoperative. Hydraulic fluid spills into the tail section.	Refueling is not available. Flammable fluid is a fire hazard.



Component name	Function	Failure mode	Effects	Remarks
HOSE TENSION REGULATOR (contd.)		Inlet port from extend solenoid valve leaking or disconnected	Snubbing at the trail position will be abnormally abrupt. Response is inoperative. Retraction may be sluggish. Hydraulic fluid spills into tail section. Loss of fluid eliminates refueling capability.	Refueling is not available. Flammable fluid is a fire hazard.
		Inlet port from retract solenoid valve leaking or disconnected	With electrical power on in the D-704, the drogue will eject and extend. Drogue cannot be retracted. Hydraulic fluid spills into tail section. Loss of fluid eliminates refueling capability.	Refueling is not available. Flammable fluid is a fire hazard. Drogue may extend unsnubbed.
		Slider jam in neutral position	Hose reel drive motor cannot rotate. Hose reel is inoperative.	Refueling is not available. Drogue position remains constant.
		Slider jam in extend position	Drogue will extend unsnubbed to the trail position whenever D-704 electrical power is on.	Refueling is not available. Drogue position remains constant.
		Slider jam in partial retract (reel-in response) position or full retract position	Drogue will retract into D-704.	Refueling is not available. Drogue position remains constant.
		Slider break radial to longitudinal axis	Hose reel cannot extend hose during response or extension.	Refueling is not available.

Component name	Function	Failure mode	Effects	Remarks
HOSE TENSION REGULATOR (cont.)		Slider break longitudinally	Hose reel is driven to retract.	Refueling is not available.
			Hydraulic power to the reel will be degraded or eliminated resulting in an inability to operate the reel in the retract direction during response or retraction.	Refueling is not available.
			Hydraulic fluid from the system pressure port will enter the inlet and flow in a reverse direction to the retract solenoid valve and then to the return line. This will cause incorrect positioning of the slider during attempted retraction. Retraction may become inoperative.	Refueling is not available.
		Plunger in inlet port from extend solenoid broken	Reel drive motor will receive hydraulic power for retraction during extension and response operation. Drogue will partially or completely retract.	Refueling is not available.
			Extend solenoid valve, when open, will supply pressure to move the slider directly instead of moving slider via plunger. Partial or complete retraction or improperly operating response will result.	Refueling is not available.

Component name	Function	Failure mode	Effects	Remarks
FUEL PUMP SHUT-OFF Switch	Disarm fuel pump solenoid valve circuit whenever less than half of the refueling hose is deployed	Open circuit, jammed open	Fuel pump solenoid valve cannot be energized. Fuel pump does not operate.	Refueling is not available.
		Sparks or heating	Ignition of spilled flammable fluids is possible.	Fire hazard exists.
		Short or jammed closed	Fuel pump solenoid valve circuit is armed at all times.	Refueling is available. If receiver aircraft is forward of the refueling range limit and the hose breaks, fuel will spew into the freestream and may impinge on the receiver.
TRAIL POSITION Switch (T-7)	Energize extend cut-out relay and switch T-8 via switch T-6	Open circuit, jam open	Extend cut-out relay is not energized when drogue reaches trail position. Drogue snubbing by choking the flow from the reel drive motor does not occur. Drogue snubbing by the hose tension regulator being positioned by the level wind will occur but may be inadequate.	Hose may break upon reaching trail position during extension.
			Switch T-8 is not energized when drogue reaches trail position. The ready light will not illuminate. Fuel transfer switch is not energized and fuel transfer to receiver aircraft cannot be accomplished. Drogue position indicator shows erroneous position.	Refueling is not available.

Component name	Function	Failure mode	Effects	Remarks
TRAIL POSITION Switch (T-7) (contd)		Open circuit, jam open (contd)	Response is inoperative. Retraction will be slow and possibly incomplete.	Refueling is not available.
			If failure occurs after drogue has extended to trail position, there is no adverse effect until the drogue is fully retracted and then re-extended.	Refueling is available until the drogue is retracted.
		Jam closed	During drogue extension, the extend cut-out relay will be energized when switch T-6 closes. This will terminate extension with only a few feet of hose deployed.	Refueling is not available.
			If failure occurs after drogue extends to the trail position, hose reel operates properly until after the drogue is retracted and re-ejected.	Refueling is available until drogue is retracted.
TRAIL POSITION Switch (T-8)	Energize ready light and fuel transfer switch	Open circuit, jam open	Ready light and drogue position indicator do not register the proper drogue position when drogue is at trail position.	Tanker aircraft pilot may pressurize hose prematurely since fuel transfer pump can be operated at trail position. This increases the force required for a receiver aircraft to engage the MA-2 coupling.
		Jam closed	Fuel transfer is inoperative. The ready light will illuminate whenever the extend cut-out relay is energized.	Refueling is not available.

Component name	Function	Failure mode	Effects	Remarks
FLOW REGULATOR VALVE (Extension Regulator)	Limits hydraulic flow from the reel drive motor during extension or response	Obstructed	Hose reel drive motor will not allow drogue extension. Response is inoperative.	Refueling is not available.
		Leaking or disconnected	Hydraulic fluid spills into tail section. Loss of hydraulic fluid will terminate refueling capability.	Flammable fluid is a fire hazard. Refueling is not available.
		Jam open	Flow from reel drive motor is unrestricted. Drogue extension velocity may become excessive. Snubbing at full trail may be inadequate to prevent breakage of hose.	Refueling is not available.
		Jam in regulated position	Flow to and from reel drive motor is restricted at all times. Extension and retraction may be slow. Response will be inadequate.	Refueling is not available.
FLOW REGULATOR VALVE (Retraction Regulator)	Limits hydraulic flow from the reel drive motor during retraction and response	Obstructed	Hose reel drive motor will not allow drogue extension. Response is inoperative.	Refueling is not available.
		Leaking or disconnected	Hydraulic fluid spills into tail section. Loss of hydraulic fluid will terminate refueling capability.	Refueling is not available.

Component name	Function	Failure mode	Effects	Remarks
FLOW REGULATOR VALVE (Retraction Regulator) (contd)		Jam open	Flow to hydraulic motor is unrestricted. Drogue retraction velocity may become excessive. Reel-in snubbing may be inadequate to prevent damage to hose, level wind, and other components. Response will be excessive at times.	This failure is more critical at lower refueling airspeeds and slower closing velocities of the receiver aircraft.
		Jam in regulated position	Flow to and from reel drive motor is restricted at all times. Extension and retraction may be slow. Response will be inadequate.	Refueling is not available.
RELIEF VALVE (between flow regulator valves)	Permit pressure spikes to vent to the hydraulic return line	Jam closed	Pressure spikes caused by rapid reversal or stoppage of reel drive motor rotation are not relieved.	These pressure spikes will travel through the pressurized hydraulic lines and may induce damage in other components.
			The trail position snubbing will be inadequate due to slow response of the reel drive motor when it reverses direction without a relief for the pressure spike. Loss of hose may occur.	Refueling is not available.
		Break or jam open	Hydraulic pressure will continuously vent to the return line.  Drogue may inadvertently eject when power is on to D-704 store.  Drogue extension speed may be excessive and trail position snubbing may be inadequate. Loss of hose may occur.	Refueling is not available.

Component name	Function	Failure mode	Effects	Remarks
RELIEF VALVE (between flow regulator valves) (cont.)		Break or jam open (cont.)	Response may be inadequate. Hydraulic system pressure may decrease sufficiently to prevent hose reel priority valve from opening or hose reel lock may engage. Drogue retraction may be inoperative.	Refueling is not available. Refueling is not available.
RETRACT SOLENOID VALVE	Permit hydraulic pressure to reach one inlet of the hose tension regulator valve	Jam closed, inlet or outlet obstructed	Drogue will extend when ON/OFF/DUMP switch is positioned to ON.	Refueling is available.
		Jam open, open circuit, return line outlet obstructed	Drogue will not retract.	Refueling is available.
			Drogue will not extend.	Refueling is not available.
			If failure occurs after drogue ejection or after full extension, drogue retracts.	Refueling is not available.
		Vent port obstructed	Piston shaft seal leakage is not vented. Piston may jam.	
		Leaking or disconnected inlet, outlet, or return line outlet	Hydraulic fluid spills into tail section. Loss of fluid eliminates refueling capability.	Flammable fluid is a fire hazard. Refueling is not available.

Component name	Function	Failure mode	Effects	Remarks
EXTEND SOLENOID VALVE	Permit hydraulic pressure to reach slider actuating plunger on hose tension regulator valve	Jam closed, inlet or outlet obstructed	Trail position snubbing by closing return port of hose tension regulator does not occur. Snubbing by reverse flow through the hydraulic motor may be inadequate to prevent hose breakage.	
			Response is inoperative.	Refueling is not available.
		Jam open, open circuit, or relief outlet obstructed	Drogue retraction may be slow or incomplete.	
			Hose tension regulator plunger remains actuated. Drogue will cease extension at time of failure.	Refueling is not available. (Drogue can be retracted.)
		Vent port obstructed	Piston shaft seal leakage is not vented. Piston may jam.	
DROGUE STOWED Switch (T-5)	Energize extend cut-out relay, transfer switch holding coil, and trail position switch (T-7)	Leaking or disconnected inlet, outlet or return line outlet	Hydraulic fluid spills into tail section. Loss of hydraulic fluid eliminates refueling capability.	Flammable fluid is a fire hazard. Refueling is not available.
		Fail open, open circuit, lever jammed or broken, spring broken	Refer to failure mode for trail position switch (T-7) open circuit.	
			Refer to failure mode for holding coil of transfer switch open circuit.	



Component name	Function	Failure mode	Effects	Remarks
DROGUE STOWED Switch (T-5) (contd.)		Fail open, open circuit, lever jammed or broken, or spring broken (contd.)	Extend cut-out relay does not open extend solenoid valve at trail position during extension.	Refer to extend solenoid valve jammed closed failure mode.
			Response is inoperative.	Refueling is not available.
		Fail closed	Retraction may be slow or incomplete.  Holding coil of transfer switch is energized whenever low level float switch is closed. Ram air turbine will not feather.	Refueling is available.
PRESSURE Switch	Inhibit firing of guillotine whenever hydraulic pressure is sufficient to hold the switch open	Jammed open, open circuit	Guillotine cartridge cannot be fired.	Refueling hose cannot be jettisoned.
		Jammed closed, obstructed inlet	Guillotine cartridge will fire whenever guillotine switch is positioned to CUT. Rotation of the hose reel may occur since reel lock may not be engaged. Damage to refueling hose or extrusion of hose end from guillotine may result in fuel spillage in the tail section.	
FLOW SWITCH RELAY	Energize transfer light whenever flow indicator switch closes	Open circuit, jam open	Transfer light will not illuminate.	Refueling is available. Receiver pilot can monitor fuel quantity to verify fuel transfer.
		Jam closed	Transfer light illuminates whenever ON/OFF/DUMP switch is positioned to ON.	Refueling is available.

Component name	Function	Failure mode	Effects	Remarks
EXTEND CUT-OUT RELAY	De-energize extend solenoid valve and energize trail position switch T-8	Jam open, open circuit	Extend solenoid valve remains closed. Fuel transfer is not available. Response is inoperative.	Refueling is not available.
		Jam closed	Extend solenoid valve will remain open. Ready light will illuminate.	Refer to extend solenoid failure modes.
DIMMING RELAY	Dim transfer and ready lights	Open circuit, jammed in bright position	Transfer and ready lights cannot be dimmed.	
		Jammed in dim position	Transfer and ready lights operate on dim setting regardless of BRIGHT/DIM switch position.	
TAILCONE LIGHTS	Illuminate tailcone	Open circuit, burned out bulb	Tailcone illumination is reduced or eliminated depending on number of bulbs affected.	Refueling is available. Night refueling may be difficult or hazardous.
READY LIGHT	Indicate D-704 is ready for receiver aircraft to engage drogue	Open circuit, burned out bulb	Ready light does not illuminate.	Refueling is available. (Ready light merely advises that drogue has reached trail position.)
TRANSFER LIGHT	Indicate fuel transfer is occurring	Open circuit, burned out bulb	Transfer light does not illuminate.	Receiver aircraft pilot can monitor fuel quantity to verify fuel transfer.
MA-2 COUPLING	Connect to receiver aircraft refueling probe for transfer of fuel	Disconnect from hose	Hose extension is inoperative. Response or retraction modes will rewind hose rapidly. Fuel may spill into airstream or tail section.	Refueling is not available. Pilot of tanker aircraft should guillotine hose.
		Poppet jam open, broken spring	Fuel will leak from coupling into airstream whenever hose contains fuel.	Refueling is not available.

Component name	Function	Failure mode	Effects	Remarks
MA-2 COUPLING (contd.)		Poppet jam closed	Receiver aircraft cannot engage coupling.	Refueling is not available.
		Ball joint binding	Drogue may become unstable as ball joint can cock the drogue to the relative wind.	Refueling is not available.
		Roller jam	Receiver aircraft cannot engage coupling.	Refueling is not available.
			Receiver aircraft may damage refueling probe or hose or drogue assembly upon disengagement.	Refueling is not available.
		Obstructed port to roller	Roller force resisting disengagement will not be increased by fuel pressure during transfer.	Refueling is available. Inadvertent disengagement is more likely than normal.
		Obstructed fuel inlet	Fuel transfer capability is reduced or eliminated.	Refueling is not available.
		Roller spring broken	Roller force is eliminated for engagement and is reduced during fuel transfer.	Refueling is available. Inadvertent disengagement is more likely than normal.
		Jam with drogue stowed or broken	Drogue cannot be ejected. Attempted extension will damage hose and may spill fuel into tail section.	Refueling is not available.
EJECTION SPRING AND COLLAR	Eject drogue during extension	Jam with drogue deployed	Drogue cannot be stowed.	Refueling is available.

Component name	Function	Failure mode	Effects	Remarks
NIGHT LIGHTING RAM AIR TURBINE GENERATOR	Supply electrical power to drogue lights	Open circuit, jam, turbine separate from generator	Drogue lights do not illuminate.	Refueling is available. Night en- gagement may be abnormally diffi- cult due to lack of drogue illumi- nation. Receiver aircraft probe light and ambient light may be adequate.
DROGUE LIGHT(S)	Illuminate drogue and coupling assembly	Burned out bulb, open circuit	Drogue illumination is reduced or eliminated depending on number of bulbs affected.	Refueling is available. Night en- gagement may be abnormally diffi- cult due to lack of drogue illumi- nation. Receiver aircraft probe light and ambient light may be adequate.
PARADROGUE ASSEMBLY	Place hose in tension and act as target for receiver aircraft refueling probe	Jam in tailcone	Drogue will not extend.	Refer to failure mode for ejection spring.
		Leaves (arms, feathers) bent or canopy torn	Drogue is unstable.	Refueling is not available.
		Leaf intercon- necting cable broken	Drogue is unstable.	Refueling is not available.
		Jam in folded position	Drag is insufficient and target is not usable.	Refueling is not available.
		Jam in open position	Drogue cannot be stowed.	Refueling is available.
		Broken or disconnected	Hose is unstable.	Refueling is not available.

Component name	Function	Failure mode	Effects	Remarks
LUG	Attach D-704 to tanker aircraft	Broken, disconnected	D-704 detaches from aircraft. Damage to tanker aircraft may well result in loss of aircraft.	
HARDBACK	Transfer store loads to lugs and sway braces	Fracture	D-704 will disintegrate.	
SKIN	Structural stress member, contains fuel, aerodynamic shape retention	Fracture	Fuel leakage or D-704 disintegration may occur.	
INTEGRAL FUSELAGE RING	Structural member	Fracture	D-704 may disintegrate.	
FORWARD BULKHEAD	Retains fuel, structural member	Fracture	Fuel will spill into nose section. D-704 may disintegrate.	Flammable fluid is a fire hazard.
AFT BULKHEAD	Retains fuel, structural member	Fracture	Fuel will spill into tail section. D-704 may disintegrate.	Flammable fluid is a fire hazard.
NOSE CONE	Structural and aerodynamic member	Fracture or disconnect	Loss of nose cone may induce other failures in nose section.	
TAIL CONE	Structural and aerodynamic member	Fracture or disconnect	Loss of tailcone may induce other failures in tail section. Hose and drogue may be ripped away.	
HOSE REEL FRAME	Support hose reel assembly	Fracture or disconnect	Reel may exit from D-704 with resultant damage capable of disintegrating D-704.	
HOSE GUIDE ROLLERS	Reduce friction on hose as it passes through level wind	Broken, jammed, disconnected	Increased friction will accelerate hose wear and may cause hose to jam in level wind.	

Component name	Function	Failure mode	Effects	Remarks
FUEL PRESSURE RELIEF VALVE (on stores so equipped)	Relieve excessive fuel line pressure	Break or jam open (at relief port) or open at an abnormally low pressure	Fuel flows from valve into fuel tank of D-704. Pressure and flow rate of fuel transfer decrease. Fuel shut-off valve may close and eliminate transfer capability.	Refueling is not available.
		Jam closed or obstructed (at relief port)	Excessive fuel pressure will not be relieved. Excessive pressure may rupture any fuel system component downstream of the fuel pump. Excessive pressure may be transmitted to receiver aircraft.	Flammable fluid is a fire hazard in tail section. Refueling is not available.
		Obstructed inlet or outlet	Fuel transfer is reduced or eliminated.	Refueling is not available.

Appendix B  
FAILURES RELEVANT TO SAFETY

Failure mode	Data source			
	D-704 NAVSAFECEN mishap data	D-704 NAVSAFECEN safety UR data	31-300 NAVSAFECEN mishap data	31-300 NAVSAFECEN safety UR data
Fire .....	5	1	0	0
Explosion .....	2	1	0	0
Guillotine failure .....	52	8	5	0
Inadvertent hose jettison .....	16	15	1	0
Uncommanded hose jettison .....	4	3	1	1
Ram air turbine .....	26	4	2	0
Structural failure .....	6	4	1	6
Reel lock .....	7	8	0	0
Hydraulic tube at reel lock .....	8	0	0	0
Pump to filter tube or fitting .....	6	17	0	0
Hydraulic reducer .....	11	8	0	0
Hydraulic pump .....	17	7	0	0
Hydraulic leak .....	139	34	3	0
Snubbing malfunction .....	101	11	0	0
Retract malfunction .....	149	23	9	0
Response malfunction .....	73	7	3	0
Wiring harness .....	6	29	1	1
18-15, T-5/6, T-7/8 switch .....	6	1	0	0
Switch arm .....	7	0	0	0
Uncommanded drogue extension .....	15	3	1	0
Hose defect .....	14	10	0	0

Appendix C  
D-704 FIRE SUMMARY

Year	Aircraft	Fire	Explosion	Guillotine Actuated	Hose Jettison	Store Jettison	Aircraft Damage	Remarks
1971	A-7B	x		x	x			Store was brought back. Investigation showed guillotine ignited flammable fluid (hydraulic). Breech cap electrical connector disengaged from retaining ring.
1971	A-7B	x		x	x	x		Fire at time of guillotine actuation.
1973	A-7E	x		x	x	x		Fire observed 30 or 40 minutes after guillotine actuation.
1978	A-6E	x	x				Alpha	Crew ejected after fire/explosion occurred during refueling.
1979	A-7E	x	x	x	x	x		Fire observed momentarily at time of guillotine actuation. Store jettisoned minutes later due to reappearance of visible flames.
1979	A-7E	x	x	x	x	x		Fire at time of guillotine actuation.



Appendix D  
REFUELING STORE STRUCTURAL FAILURES

Sources: NAVSAFECEN mishap data and safety UR data.

Failure	No. failures
D-704	
KA-6D overpressurization ruptures	2
Pressure fueling ruptures (on ground)	1
Station 71	
Cracks	1
Failure (complete loss of forward end of store)	1
Center section weld ruptures in flight	2
Aft bulkhead cracks	1
Drum mount structure failed	1
Reel lock mounting failed	1
31-300	
Tailcone lost in flight	1
Tailcone section lost in pressure fueling	1
Crack in rib near ram air turbine/hydraulic pump mount	1
Leaks at suspension lugs due to cracks	4

Appendix E  
MISHAPS BY AIRCRAFT TYPE

Aircraft	D-704 mishaps	31-300 mishaps	Period
A-4 .....	55	7	1969-79
A-6 .....	124	6	1969-79
A-7 .....	179	5	1970-79
Total .....	358	18	

Appendix F  
3-M FAILED PARTS DATA

WUC <sup>a</sup>	Nomenclature	Part no.	Manufacturer's code	System <sup>b</sup>	Application <sup>c</sup>	Aircraft	Failures	MAL code <sup>d</sup>	Remarks
46722	Float and vent pilot valve	95186	79326	F	B	A-4	1	160	
4673D	Flow regulator valve	ANS0910R13	79470	H	B	A-4	50	020	
4674C	Ready light	AN622716 1385	79470 72914	H E	B B	A-4 A-4	12 12	381 080	Packing (O-ring) Lamp
			24446	E	B	A-4	2	080	Lamp
			93519	E	B	A-4	1	080	Lamp
			96906	E	B	A-4	1	080	Lamp
4674D	Transfer light	MS35487	72914	E	B	A-4	2	080	
46773	Hose cutter (guillotine)	...	...	...	B	A-4	0	...	
46774	Refueling hose	...	...	...	B	A-4	0	...	
46A32	Fuel shutoff valve	MS29513 MS29513-221 110757	88277 96906 83259	F F F	D D D	A-4 A-4 A-4	1 2 1	070 381 070	Packing Packing
		46001524	83259	F	D	A-4	1	070	
		600015140S	83259	F	D	A-4	2	070	
		730800	96124	F	D	A-4	1	070	
46A33	Fuel pump	MDP8A MS29513253 2664438	71400 88277 18355	F F F	D D D	A-4 A-4 A-4	4 1 1	080 381 020	Packing
46A3A	Pilot float and vent valve	...	...	F	D	A-4	0	...	
46A63	Refueling hose	18-50	28474	F	D	A-4	2	070	
46C38	Fuel pump	...	...	F	S	A-4	0	...	
46C65	Refueling hose	18-50	28474	F	S	A-4	1	070	
466D100	D-704	AN450K12AD16 AN50910R13	88044 88044 or 88277	...	D D D	A-6 A-6 A-6	99 28	585 585 585	
		DV632754	15786	...	D	A-6	36	070	Drogue cable (between leaves)
		DV632764	15786	...	D	A-6	36	070	Drogue cable (between leaves)
		DV632770	15786	...	D	A-6	36	070	Drogue cable (between leaves)
		DV632778	15786	...	D	A-6	36	070	Drogue cable (between leaves)
		FG1001100	15198	...	D	A-6	14	615/450	(and other MAL codes), electrical connector
		MIL-W-7139B	81349	...	D	A-6	99	160	
		MS2469452	18355	...	D	A-6	40	070	Screw
		MS28782	81873	...	D	A-6	12	020/381	
		DS1652	15786	...	D	A-6	25	780/070/585	

See footnotes at end of table.

Appendix F (Contd.)

WUC <sup>a</sup>	Nomenclature	Part no.	Manufacturer's code	System <sup>b</sup>	Application <sup>c</sup>	Aircraft	Failures	MAL code <sup>d</sup>	Remarks
4661100	11-704 (contd.)	152C50291	72429	...	D	A-6	36	070	Rivet in S-F drogue tip
		152C50292	72429	...	D	A-6	36	070	
		152C50293	72429	...	D	A-6	36	070	
		152C50294	72429	...	D	A-6	36	070	
		16010512	15786 or 88277	...	D	A-6	198	585	
4661300	(Refueling hose)	18-50	28474	F	D	A-6	20	070	
			70168		D	A-6	1	070	
			42429		D	A-6	1	381	
			75237		D	A-6	1	093	
			81873		D	A-6	1	093	
46A20	Structural system		88267		D	A-6	1	070	
			88277		D	A-6	3	070	
		323975	00779	...	D	A-6	50	160	
		AN50910R11	79249	...	S	A-6	12	020	
		AN50910R9	79249	...	S	A-6	12	020	
46A30	Fuel system	AN52K10R7	79249	...	S	A-6	32	020	Screw
		AN50910R13	30081	S	D	A-7	28	170	
		R4G	71286	S	D	A-7	12	170	
		40G10	71286	S	D	A-7	12	170	
		40025	71286	S	D	A-7	12	170	
46A32	Fuel shutoff valve	MS287784	81873	F	D	A-7	12	242	Drogue shoe
		MS29513134	88277	F	D	A-7	13	242	
		MS29513236	88277	F	D	A-7	12	242	
		NAS2218	88277	F	D	A-7	18	242	
		4546972	88277	F	D	A-7	18	242	
46A33	Fuel pump	4555616	88277	F	D	A-7	1	020	(and other MAL codes)
		2332702003	77200	F	D	A-7	1	242	
		18-50	28474	F	D	A-7	27	780/070	
		MS21900D4	03647	F	D	A-7	1	070	
		MS21900D6	03647	F	D	A-7	1	070	
46A37	Pilot float and vent valve	MS219424L	83205	F	D	A-7	1	381	Adaptor on press. fuel receptacle Bulkhead adapter Hydraulic Tee at control valve Restrictor in float and vent valve Float and vent valve
		S225388716D609	88277	F	D	A-7	1	070	
		4665941168000	88277	F	D	A-7	1	070	
		9125471	82267	F	D	A-7	1	170	

See footnotes at end of table.

Appendix F (Contd.)

WUC <sup>a</sup>	Nomenclature	Part no.	Manufacturer's code	System <sup>b</sup>	Application <sup>c</sup>	Aircraft	Failures	MAL code <sup>d</sup>	Remarks
46A40	Electrical system	1385	08806	E	D	A-7	5	080	Light bulb
			16316	E	D	A-7	5	080	Light bulb
			72914	E	D	A-7	7	080/567	Light bulb
			76090	E	D	A-7	2	080	Light bulb
			80378	E	D	A-7	1	080	Light bulb
46A42	Transformer-rectifier	1385W	96906	E	D	A-7	4	080	Light bulb
			12228	E	D	A-7	1	080	Light bulb
			11114	E	D	A-7	1	450	Light bulb
46A53	Console	28VFT	94988	E	D	A-7	1	070	
			58BL180	...	D	A-7	16	450	
46A61	Drogue coupling assembly Lighted drogue assembly	NAS2218 DU632754A141 DU632764A142 DU632770A143 DU632778A144 DV632754A145 DV6327548136A1 DV632764A146 DV6327648136A1 DV632770A147 DV6327708136A1 DV632778A148 DV6327788136A1 1384 1385 1394	80205	...	D	A-7	12	070	
			15786	...	D	A-7	36	105	
			15786	E	D	A-7	36	105	
			15786	E	D	A-7	36	105	
			15786	E	D	A-7	36	105	
			15786	E	D	A-7	36	070	Drogue cable
			15786	E	D	A-7	36	070	Drogue cable
			15786	E	D	A-7	36	070	Drogue cable
			15786	E	D	A-7	36	070	Drogue cable
			15786	E	D	A-7	36	070	Drogue cable
			15786	E	D	A-7	36	070	Drogue cable
			15786	E	D	A-7	36	070	Drogue cable
			24455	E	D	A-7	2	080	Lamp
			72914	E	D	A-7	3	080	
			24455	E	D	A-7	1	080	
46A63	Drogue fuel hose (refueling hose)	18-50 18-50 (1T25)	28474	F	D	A-7	6	070	
			62793	F	D	A-7	1	780	
46A67	Hose cutter (guillotine)	2547024 262493 2672493 2675128 2675129 3010609 3668033	28474	F	D	A-7	1	070	
			88277	...	D	A-7	1	105	Nut (in float and vent valve)
			88277	...	D	A-7	1	020	
			88277	...	D	A-7	1	020	Anvil (guillotine)
			88277	...	D	A-7	2	900	Piston (guillotine)
			88277	...	D	A-7	1	900	Nut (guillotine)
			88277	...	D	A-7	3	093	
			88277	...	D	A-7	1	585	Guillotine

See footnotes at end of table.

Appendix I: (Contd.)

WUC <sup>a</sup>	Nomenclature	Part no.	Manufacturer's code	System <sup>b</sup>	Application <sup>c</sup>	Aircraft	Failure	MAL code <sup>d</sup>	Remarks
46A67	Hose cutter (contd.)	3672055 3672448 4669727501 4669727503 4672372 4674605 9125471	88277 88277 88277 88277 88277 88277 88277	... ... ... ... ... ... ...	D D D D D D D	A-7 A-7 A-7 A-7 A-7 A-7 A-7	5 1 1 1 6 2 1	020/070 135 070 020 190 900 070	(and other MAL codes), guillotine wire Anvil Support (guillotine) Support (guillotine) Knife Plug (guillotine cylinder) Float and vent valve
46C18	Pressure actuated shutoff	...	...	F	S	A-7	0	...	
46C35	Pressure float & vent valve	9125445	92003	F	S	A-7	1	020	
	Fuel hose (refueling hose)	18-50	26479	F	S	A-7	1	780	
46C38	Fuel pump	...	28474	F	S	A-7	1	780	
46C40	Electrical system	GE1385 GE1585 MS25237328 1384	24446 24446 24446 24446	F E E E	S S S S	A-7 A-7 A-7 A-7	0 2 2 1	... 080 080 080	Lamp
46C61	Guillotine Assy	3672055	24446	E	S	A-7	2	080	Lamp
46C65	Refueling store hose	...	88277	...	S	A-7	2	160	Guillotine wire
		...	...	F	S	A-7	0	...	

<sup>a</sup> WUC work unit code.<sup>b</sup> System codes:

F - fuel  
H - hydraulic  
E - electrical  
S - structural

<sup>c</sup> Application codes:

B - on both D-704 and Sargent-Fletcher 31-300 stores  
D - D-704

S - SF-31-300

<sup>d</sup> MAL code malfunction code.

## NWC TP 6218

Appendix G  
3-M PARTS REMOVAL DATA

Nomenclature	Part no.	Manufacturer's code	Aircraft	Removals	Remarks
Probe nozzle	2630110	92003	A-4	3	
Fuel shutoff valve	730800	96124	A-4	3	
Control/instrumentation	B478-32	36536	A-4	5	
Fuel flow indicator	8DJ96LAF1	97424	A-4	8	
		77045	A-4	13	
Fuel flow transmitter	8TJ59GAL12	24446	A-4	11	
		97424	A-4	17	
Air refueling stores	13G1-586595M2	92003	A-6	14	
	208-5003	72429	A-6	26	
	5668927-501	03034	A-6	6	Control box
		88277	A-6	14	Control box
	5668927-503	88277	A-6	20	Control box
		10001	A-6	4	Control box
	6503800	77200	A-6	1	Ram air turbine
		70168	A-6	8	Ram air turbine
Hydraulic pump	AA65674-L6	62883	A-7	13	
Ram air drive power unit	6503800	70168	A-7	31	
Dump valve	1319556275M2	92003	A-7	8	
Fuel hose	18-50	28474	A-7	8	
Pilot float and vent valve	9-1254-71	82267	A-7	5	
		92003	A-7	4	
Interconnection cable	2187715-2	93563	A-7	18	
		80378	A-7	9	
Control/instrumentation	QP30895-1	88277	A-7	19	
	5668927-503	88277	A-7	11	
Air refueling console assembly	5668927-501	98162	A-7	5	
Drogue installation	5547048-503	15786	A-7	2	
		88277	A-7	4	
		81823	A-7	1	
Drogue coupling assembly	5823332-1	88277	A-7	4	
	7-653-181-2	92003	A-7	4	
		82267	A-7	2	
Lighted drogue assembly	5547048-501	18355	A-7	4	
		88277	A-7	2	
	5547048-503	88277	A-7	6	
Hose cutter assembly	Mk 1 Mod 3	05375	A-7	25	
	Mk 2 Mod 1	05375	A-7	10	
	M365	30003	A-7	7	
	3668033	88277	A-7	5	
		28474	A-7	2	
NOC <sup>a</sup>	1-1HM-0277	30003	A-7	9	

<sup>a</sup> Not otherwise coded.

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